

Review Articles

Load carriage: minimising soldier injuries through physical conditioning – a narrative review

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Abstract

Background: With soldiers carrying increasing loads, physical conditioning may provide one means of reducing injuries and increasing the ability to train, maintain and retain soldiers.

Purpose: The purpose of this study is to review the current literature on physical conditioning for load carriage and present the findings in a manner that will allow physical conditioning practitioners a means of applying them in a conditioning program.

Methods: Using key search terms, a literature search of academic databases (both civilian and military) was conducted, with additional relevant literature sought from military and civilian colleagues. Gathered papers were assessed against several key criteria and limited to those relating specifically to physical conditioning and military load carriage. These papers were reviewed to glean key findings in the light of information from additional sources that were employed to contextualise the findings.

Results: The search results yielded seven original research papers, one conference paper and four secondary source papers (military reports, journal articles).

Conclusions: Research suggests that, while other forms of conditioning may be of a supplemental benefit, an effective load carriage conditioning program will include specific load carriage training conducted between two and four times per month. Loads must be sufficient to elicit a physiological response proportionate to that recommended for cardiovascular and metabolic fitness development, with the duration and distance gradually progressed to levels that meet training and operational needs. While higher intensity training may be of particular value, excessive training volume may increase the risk of both acute and overuse injury risks.

Introduction

Military personnel are required to carry loads as part of their occupation - loads that, in excess, have altered battle tactics and led to soldier deaths in previous conflicts¹. With recent evidence suggesting that soldiers are now carrying more load than ever before², there is potential for the injuries and casualties caused by load carriage practices to impact on force generation (the pool of personnel undergoing training and development) and force maintenance (the pool of deployed and deployable personnel).

Acknowledged as placing stress on the musculoskeletal system of the carrier³, load carriage tasks have the potential to cause a variety of injuries ranging from blisters, lower back injuries and knee and foot pain^{2,4,6}, to stress fractures, and brachial plexus palsy^{2,6,7}. With low fitness levels associated with an increase in the risk of injury during general military training⁸ and load carriage tasks in particular², physical conditioning to increase fitness levels can provide a

means of limiting load carriage injuries². This concept of conditioning soldiers to carry loads is not new and can be traced back to the Roman Legionnaires⁹. What is lacking however, are practical guidelines on how to condition military personnel for load carriage tasks; a translation of research findings into practice.

The aim of this paper is twofold. Firstly, the paper will review current literature to determine evidence-based best practice for load carriage conditioning. Secondly, the findings will be presented in a format similar to those used by physical educators and trainers to develop physical conditioning programs.

Methods

Literature Search: Training for Load Carriage

Research papers and articles that included key search terms related to training and conditioning for load carriage were gathered from numerous sources in two stages. The first stage entailed using databases as an initial starting point and entered key search terms.

These databases and key search terms, which varied slightly depending on the specifics of the databases' search engine, are detailed in Table 1. No language restrictions were applied and, where possible, searches were limited to "human" subjects. In an attempt to identify further research publications of relevance to this literature review, both military and civilian colleagues were contacted.

Database	Search terms
MEDLINE (Ovid)	load AND carr*; load AND march*; pack AND march*; endurance AND march*
PUBMED	load AND carriage; load AND carry; load AND marching; load AND march; pack AND march; pack AND marching; endurance AND march; endurance AND marching.
PROQUEST	load AND carriage; load AND carry; load AND marching; load AND march; pack AND march; pack AND marching; endurance AND march; endurance AND marching.
CINAHL	load AND carriage OR carry; endurance AND march OR marching; pack AND march OR marching; load AND march OR marching.
DEFWEB	load AND carriage; load AND carry; load AND marching; load AND march; pack AND march; pack AND marching; endurance AND march; endurance AND marching.

Table 1: Details of literature search: databases used and search terms.

Once all initial papers were gathered, duplicate studies were removed and abstracts used to review and exclude papers that were clearly unrelated to load carriage by humans (eg. non-human subjects, pathology studies). The papers were then divided into three categories - original research papers, conference papers and secondary source articles (eg journal articles, relevant subject reviews and military reports) with the load carriage research and conference papers subjected to the key exclusion criteria detailed in Table 2.

The second stage of the literature search involved identifying all papers, articles and conference notes which included physical training or conditioning as part of their focus in addition to their load carriage focus. A keyword search for specific terms (program, conditioning, preparation) was also undertaken across all of the first stage documents to ensure that any further relevant literature was identified. Papers not identified through this second stage process were excluded from the review. Finally, as the aim of this paper was to investigate military load carriage, all

Exclusion Criteria	Example:
Participant ages outside typical military service age range of 16 to 65 years	Adolescents
Study included a form of mobility aid	Walking poles
Study included medical supplementation	Ergogenic aids
Study included medically unfit subjects	Idiopathic scoliosis
Study included components in an altered environment	Microgravity, high altitude
Study not published in English	
Study did not include a load carriage variable (dependent or independent); was not specifically related to a load carriage activity; or involved no physical loads being carried	General military conditioning programs
Study had a commercial interest	Commercial backpacks
Defence documents which were rated above "unclassified".	

Table 2: Exclusion criteria applied to the literature search and examples of excluded subjects.

papers (n=2) that did not include loads carried on the back in a load carriage system¹⁰ or focus specifically on load carriage conditioning¹¹ were removed from the final document set relating to training for load carriage.

Literature Review and Contextual Sources

The research reports yielded by the literature search were reviewed using a narrative approach. In order to contextualize these reports within a practical implementation framework, the reports were considered in the light of pertinent information from the broader fields of physical training. On this basis, the literature review synthesized key findings from the identified reports with information gathered from a wide range of published physical training literature. The findings are presented utilizing a funneled approach, whereby general physical training concepts are presented initially, in order to provide the necessary framework for presenting the findings of the load carriage literature review.

Search Results

Following the first stage of the literature search, 8,053 papers were identified from the databases search and 36 additional papers were gathered from colleagues and journal article reference lists. The initial exclusion of clearly non-relevant and duplicate articles reduced the number of papers to 291. From these papers, three full text articles could not be obtained through

Author (date)	Pop	Training Program	Objective Measures and % improvement	Potential confounders / biases	Publisher
Harman et al., (2008)	Civilian ♂ n=32 1) n=15 2) n=17	8 Week program 90 mins x 5 / week 1) Weight based training - Full body weight training, 3.2 km runs, intervals, agility and progressively loaded 8 km march 2) Army Standardized Physical Training - Stretching, callisthenics, movement drills, sprints, shuttle and distance runs	A) 3.2 km run with 32 kg 1) 15% (time) 2) 14% (time) B) 400m run with 18 kg load 1) 16% (time) 2) 11% (time)	Gender Background – Non military	Journal of Strength and Conditioning Research – Peer Reviewed Journal
Knapik et al., (1990)	Soldiers ♂ n=137 (started) 1) n=26 2) n=19 3) n=33 4) n=24	9 Week program 1) March x 0 / month 2) March x 1 / month 3) March x 2 / month 4) March x 4 / month All programs included progressive running, intervals, resistance training and callisthenics	20 km Road march with 46 kg load 1) – 12.9% (time) 2) – 13.9% (time) 3) – 5% (time) 4) – 7.7% (time) While all groups were slower due to longer breaks and weather variations groups 3) and 4) were 11% faster than groups 1) and 2)	Gender Diurnal variances (temperature = ave 16oC warmer) Variances in rest periods during march	US Military Technical Report
Kraemer et al., (2001)	Untrained ♀ n=93 1) n=17 2) n=18 3) n=18 4) n=15 5) n=14 6) n=11	6 Month program 3 sessions / week 1) Total body Resistance – explosive 2) Upper body Resistance – explosive 3) Total body Resistance – traditional 4) Upper body Resistance – traditional 5) Field – plyometrics 6) Aerobic NOTE: All groups included supplemental aerobic exercise NOTE: No load carriage conditioning	A) 3.2 km loaded run with 44.7 kg as fast as possible 1) ± 10% (time) 2) ± 6.5% (time) 3) ± 11% (time) 4) ± 11% (time) 5) ± 11% (time) 6) – 1% (time)*	Gender Age (means 21.1-24.8 years) Untrained Background – non military	Medicine & Science in Sports & Exercise – Peer Reviewed Journal
Kraemer et al., (2004)	Soldiers ♂ n=35	12 Week program 4 sessions/week 1) Resistance + endurance trg 2) Upper body resistance + endurance trg 3) Resistance trg only 4) Endurance trg only NOTE: No load carriage conditioning	A) 3.2 km loaded run with 44.7 kg as fast as possible 1) 14% (time) 2) 10.8% (time) 3) 4.2% (time) 4) 0.5% (time)	Gender Age (means 21.4-24.3 years)	Military Medicine – Peer Reviewed Journal
Patterson et al., (2005)	Soldiers March 1: ♂ n=34 ♀ n=28 March 2: Soldiers ♂ n=18 ♀ n=12	12 Week program 1) Specialised training group - 60 min sessions x 3 / week with circuit training, run sessions and 2 x marching sessions (1 x 25 min; 1 x 30 min) 2) Control group - Standard unit physical training programs (not detailed)	A) 15 km march with a load of 34.6 kg at a target speed of 5.5 km/h 1) N/S (completion rate) 2) N/S (completion rate) B) Run, Dodge and Jump Course 1) N/S (time / completion rate) 2) N/S (time / completion rate)	Diurnal variety between Aug and Nov trials Drop out rates No details provided on unit physical training programs Only two short load carriage sessions in 12 week period Pace was set for the loaded march assessment	Australian Military Technical Report
Rudzki (1989)	Soldiers ♂ n=93 1) n=46 2) n=48	11 Week program 1) Run Group Standard endurance program (Run and march) 2) March group - Loads: 16.2 kg (Weeks 1-3), 18.6 kg (Week 5), 21.2 kg (Week 6), 23.8 kg (Week 7), 26.4 kg (Week 8), 29 kg (Week 9), Field equipment (Week 10); dressed in fatigues with rifle - Speed: 5 km /h up to week 6, then 7.5 km/h for	A) Aerobic fitness on Monark cycle ergometers. 1) 11.97% (VO2) 2) 8.6% (VO2)	Gender Age (means: 1) 19.9 years; 2) 19.6 years) Two different platoons with different staff No balance order therefore subject to individuality of group Drop out rates of 20% per group (although equal between groups)	Military Medicine – Peer Reviewed Journal
Williams et al., (1999)	Soldiers ♂ n=47 ♀ N = 10	10 Weeks of basic training 71 periods of 40 min physical training with prolonged marching and loads on military exercises	A) Loaded march over 3.2 km as fast as able with 15 kg (LM15) or 25 kg ♀ only (LM25) - LM15 3.6% (time) - LM25 15.7% (time) B) Aerobic fitness via 20m shuttle run - 6.1% (VO2 max)*	Age (means: ♂ = 19.4; ♀ = 21.4) Two different platoons with different staff No females in the platoons that had significant finds Learning effect due to presentation order	Ergonomics – Peer Reviewed Journal
Visser et al., (2005)	Soldiers ♂+♀ n=50	8 Weeks 1) Load 20-32% (♀) or 25-40% (♂) BW, 8.3-16.5 km per session, weekly 2) Load 20-32% (♀) or 25-40% (♂) BW, 8.3-16.5 km per session, fortnightly 3) Load 35-55% (♀) or 45-67.5% (♂) BW, 4.1-5.5 km per session, weekly 4) Load 35-55% (♀) or 45-67.5% (♂) BW, 4.1-5.5 km per session, fortnightly	A) Incremental Load March Test – Starting load 15 kg (♀) or 25 kg (♂) increasing up to 62.5 kg in 12.5 kg increments every 1000m. Speed started at 6 km/h, and if participants were able to meet all weight increases, speed was then increased by 0.5 km/h every km 1) 7% (march increments) 2) 6% (march increments) 3) 18% (march increments) 4) 9 % (march increments)	Unknown gender distribution Learning effect of incremental load test	Conference paper

Table 3: A tabulated overview of the key papers used.

library, peer or military sources and were therefore also excluded. Judging from the article titles, it is highly unlikely that these papers would have met the inclusion criteria and were therefore deemed non critical papers. Following the implementation of the listed exclusion criteria, the number of articles was further reduced to 215 (124 primary research; 32 conference; 59 secondary source). The second stage of the literature search further reduced the total number of papers to 11 (7 original research; 1 conference; 3 secondary source). A tabulated overview of these original research papers and the conference paper is presented in Table 3. The secondary source articles included a non-experimental military report⁶, a peer reviewed load carriage review² and a military journal article¹².

Literature Review Results and Discussion

The Principle of Specificity

The principle of specificity has as its essence the need to conduct task specific physical conditioning^{13,14}, supporting claims that load carriage tasks need to be included in a conditioning program designed to improve load carriage ability^{2,10,11}. As an example of the specificity concept, a study by Genaidy et al. (1989)¹⁰ had an experimental group participate in eight training sessions (2.5 weeks) replicating a repetitive lift-and-carry task (20 kg load). Following completion of the program, the experimental group significantly improved their ability to continue the repetitive lift-and-carry task by 50 % more time than the improvement time observed in the control group.

Conversely, a specialized 12-week conditioning program for Australian soldiers, which included circuit and resistance training, running, and load carriage marching, was evaluated by Patterson et al. (2005)¹⁵. The study found that, while soldiers increased in strength and aerobic capacity following the program, completion time for a 15 km march (35 kg load) and an agility course (10 kg load) did not change significantly. While seasonal temperature variations are expected to have contributed to producing this non-significant finding, limiting the physical conditioning program to only two load carriage sessions throughout the program (Week 3 and Week 5) may have also been a factor in minimizing any observable effect of the training. Furthermore, the duration of the longest conditioning load carriage march (30 minutes) was notably shorter than the duration of the 15 km event (165 minutes). This finding raises the further question of whether there is a minimum training dose (frequency, intensity and volume) required to elicit a training response for load carriage.

Conducting a study to compare the impact of different training doses on load carriage capacity, Visser et al. (1995)¹⁶ compared a high intensity (load) and low volume (distance) training regime to one of a lower intensity (load) and higher volume (distance) (detailed in Table 4). Speed was kept constant at 5.5 km/h. Both training dose combinations were reviewed against the effects of training frequency (number of sessions per week). Their study found that, while all groups improved in strength, aerobic endurance, speed of march and progressive load march performance, the higher intensity (load), lower volume (distance) groups improved to a greater degree in the progressive load march test (detailed in Table 3) than the lower intensity, higher volume groups (See Table 4). Furthermore, the groups training with a higher frequency (once per week) improved to a greater extent than those training with a lower frequency (once per fortnight)¹⁶. These findings suggest that training improvement is best facilitated by intensity (load), followed by training frequency (sessions per week) and then by volume (distance).

Training dose combinations	1 x / fortnight	1 x / week
High intensity (load), lower volume (distance) groups (35 to 67.5 % bodyweight for 4.1 to 5.5 km / session)	9.1 %	17.9 %
Low intensity (load), higher volume (distance) groups (20 to 40 % bodyweight for 8.3 to 16.5 km / session)	5.7 %	7.3 %

Table 4: Study results comparing training dose to training frequency (% improvement).

Over the longest distance march reported in the selected papers, Knapik et al. (1990)¹⁷ investigated the impact of a nine week conditioning program with the frequency of load carriage sessions ranging from none up to four sessions per month (0, 1, 2, 4 sessions per month with loads from 18 to 34 kg up to a distance of 16 km per session). The study found that the two groups training twice or more per month were 11 % faster over a 20 km distance (46 kg load). The study also found no significant differences between the groups that trained twice versus four times per month.

The differences in findings between Knapik et al. (1990)¹⁷ and Visser et al. (1995)¹⁶ regarding load carriage training frequency may lie in the markedly different training programs, most notably load carriage intensity (load) and load carriage volume (distance). The Knapik et al. (1990)¹⁷ findings may however suggest that a 'law of diminishing returns'¹⁸

exists, where fitness gains decrease with the amount of exposure (in this case training frequency).

Rudzki (1989)⁵ conducted a study comparing two 11-week recruit conditioning programs. One program consisted of endurance running, load carriage, and other conditioning activities (run group), the other replaced all the running sessions with weight load marching (load-marching group). Rudzki (1989)⁵ found that, although both groups made similar gains in aerobic fitness, the rate of development was different between each group. The run group made significant improvements in aerobic fitness in the first six weeks of the conditioning program while the load-marching group made gains in the last five weeks. In the latter case, the time period in which significant improvements occurred coincided with an increase in walking speed (from 5 km/h to 7.5 km/h) and an increase in loads carried (16.2-21.2 kg to 23.8-29 kg). While the paper does not specifically detail changes to volume (duration) or frequency (times per week) it is expected that both of these parameters increased as the field training focus increased towards the latter half of the recruit training program. Ultimately, however, these results suggest that, to make significant gains in aerobic fitness and load carriage ability, the load carriage program needs to be at an intensity (load and speed) that is sufficient to stimulate adaptation. These findings, together with those of Visser et al., (1995)¹⁶, suggest that load carriage intensity (load and speed) is a key factor in improving load carriage performance.

Contrary to the principle of specificity, improvements in load carriage ability may be made without including load carriage training in the conditioning program. In a 12 week (male soldiers)¹⁹ and a 24 week (untrained females)²⁰ study, Kraemer et al. (2001, 2004) had groups training three (untrained females) to four (male soldiers) times per week following various training protocols which included resistance training (full body or upper body, power orientated or hypertrophy orientated), and aerobic training (long distance running and sprint intervals), either in combination or in isolation. The conditioning programs that employed a combined training approach of both resistance training and aerobic training were associated with significant improvements in 3.2 km run (44.7 kg load) completion time. Interestingly, in both studies, the participants who followed programs employing either resistance training¹⁹ or aerobic training^{19,20} in isolation failed to make any significant improvements in loaded run times. The investigators suspect that upper body strength, which in turn improves posture maintenance, lead to an increase in energy efficiency and hence aided in improving load carriage task performance.

The Impact of Concurrent Training

Concurrent training involves training for more than one physiological response (e.g. strength and aerobic endurance) at the same time²¹. The results of Kramer et al (2001, 2004), noted above, suggest that, contrary to the findings of some research, which questions the value of concurrent training in contexts other than load carriage²¹, a combination of resistance training and aerobic training may be of value for load carriage conditioning. Supporting the use of concurrent training in load carriage training are the research findings of Harman et al (2008)²², who compared two physical conditioning programs. The first program followed a new U.S. Army Standardised Physical Training regime (including weight load marching, stretching, calisthenics, sprints, shuttle runs, and medium-distance runs (12-18 mins runs) and the second a weight-based training program with an increased resistance training focus (including weight load marching, full body resistance, longer-distance, ability based, runs (20-30 min runs), sprinting, and agility training). Both groups were found to make similar, significant improvements in short duration load carriage abilities (400 m with 18 kg load and 3.2 km with 32 kg load).

In a study reviewing the British Army Basic Training conditioning program, which consisted of seventy-one 40 minute periods of physical conditioning (sports, circuits, swimming and endurance sessions) as well as prolonged marches with various loads during military exercises, Williams et al. (1999) found that only one of the two platoons made significant improvements in load carriage performance²³. A male only platoon (N=33) which was assessed completing a 3.2 km distance (25 kg load) as fast as possible significantly improved in time (15.7 %), while an integrated platoon (male n=13; female n=8) failed to make a significant improvement in an assessment conducted over the same distance, in the same manner, with a lighter load (15 kg); even when the results were separated by gender. A potential reason for these differences arises from typical inter-platoon differences (e.g. platoon construct, platoon staff and daily program), making it impossible to draw firm conclusions about the value of concurrent training from these results.

The value of concurrent training is further supported by research findings which have correlated load carriage task ability with neuromuscular ability²⁴ and aerobic fitness^{15,25}. A study by Frykman et al (2000), for example, found that female soldiers who could do more push ups and sit ups had faster obstacle course times (14 kg and 27 kg loads)²⁴. Additionally, Lyons et al (2005), noted that as load increased (from 0 kg to 20 kg to 40 kg) and subjects became less efficient, a higher absolute aerobic capacity was essential for

performance during a 60-minute load carriage task (4 km/h at inclines of 0, 3, 6, and 9 %)²⁵.

With studies by Kraemer et al (2001, 2004)^{19,20} suggesting that load carriage performance can be improved with concurrent training that excludes specific load carriage training, two factors need to be considered. Firstly, it should be noted that subjects with lower levels of fitness and exercise make greater initial gains regardless of the type of training employed, after which specific training is needed to improve performance for a specific task¹¹. Secondly, specific training can impart gains other than those measured by objective means. The aforementioned study by Rudzki (1989)⁵ identified that, while both the run group and the load-marching group made similar gains in aerobic fitness, the load-marching group were subjectively rated by staff as performing better at military tasks than the run group.

The Principle of Recovery

Just as the training frequency, volume and intensity are important factors to consider in the design of a load carriage conditioning program, so too is the concept of recovery. The principle of recovery highlights the need for the systems of the body to have a sufficient recovery from the training stimulus to prevent overload and injury¹³. Failure to provide recovery in the training program and to instead employ high volumes of vigorous weight bearing activities continuously has been identified as a causal factor in high injury rates among military personnel²⁶. One means of providing recovery from a progressive training stimulus is to reduce the total volume (distance) of conditioning¹³. This volume reduction strategy has been found to dramatically reduce injury rates during recruit training, without negatively influencing fitness⁷.

With this in mind, it may be suitable to strategically place recovery periods throughout long term load carriage training programs. These 'orthopaedic holidays'²⁷ should be long enough to ensure that some musculoskeletal recovery takes place, yet short enough to limit detraining, as lengthy breaks in load carriage conditioning have been found to increase the chance of injury when soldiers return to heavy load carriage activities⁴. How long these periods should be is difficult to prescribe, as recovery requirements and detraining rates vary between different anatomical²⁷ and physiological parameters¹⁴. Consequently, a structured and progressive conditioning program with built in recovery periods is recommended. Loosely implemented in the Australian⁷ and British²⁷ defence forces, this conditioning structure has been found to decrease the incidence of military trainee injuries.

Finally, a point of caution - while load carriage conditioning may maximise an individual's load

carriage ability, there will still be a finite limit to the carrier's physical ability¹². Therefore, while a well conditioned individual may be able to carry a heavier load than someone less well conditioned, there will still be a load threshold above which they will be overloaded²⁸.

Practical Implementation

While the above findings suggest that physical conditioning may improve load carriage task performance, to be of a practical value, the load carriage research needs to be presented and applied in a manner consistent with the programming approach used for traditional physical conditioning. One such approach is the F.I.T.T. (frequency [how often], intensity [how hard], time [how long] and type of training) principle or a derivative thereof¹⁴. In this section, we attempt to present the key information for load carriage conditioning using this approach.

Frequency

As a result of their findings, Knapik et al. (1993, 2004)^{2,29} recommended that weight load marching be conducted at least two times a month with loads that soldiers are expected to carry in a unit on operations. Visser et al. (1995)¹⁶ however found greatest improvements with sessions conducted weekly versus fortnightly. Considering both of these findings, the 10-day load carriage conditioning cycle implemented in the Netherlands⁶ may in fact be the optimal frequency in the training dose. This frequency may however vary depending on training intensity (load, speed) and training volume (time or distance).

Intensity

To stimulate aerobic fitness adaptations, the load carriage conditioning intensity (eg. load, speed) needs to be sufficient enough to elicit a training response. While research has suggested higher intensity training to be of particular benefit for improving load carriage performance^{5,16}, the potential for injury following a long period of high intensity load carriage² must be considered. Ultimately, the conditioning program needs to ensure that personnel are being conditioned to carry loads at the intensities required for military exercises and operational tasks, whilst being cognisant of the fact that, no matter how much conditioning is undertaken, there is still a point beyond which the load carriage task will become too much for the carrier to physiologically withstand¹².

Time

The conditioning stimulus time (or distance) must be considered against both the intensity of the task and the outcome requirements. Just as short duration, high intensity sessions can be used to develop the

ability to move rapidly for short durations (under direct fire for example)^{14,30}, longer duration sessions are needed to develop the physical and mental stamina to endure long duration tasks (dismounted patrols, for example)³⁰.

Type of Training

The principle of specificity identifies the need for the conditioning context to meet the requirements of the performance context. However, the concept of concurrent training also suggests that other forms of physical conditioning may be useful to supplement the conditioning program, especially for the less fit. The results of the reviewed research suggest that exercises which stimulate upper body strength and increase aerobic fitness, in particular, may be of benefit for load carriage, provided they do not become the focal point of the training and reduce time allocated to load carriage specific training.

Finally, the principle of recovery demands that the overall load carriage conditioning program be structured and progressive, and include musculoskeletal recovery periods to help mitigate overuse injuries. Each of these concepts is supported by the review of pertinent research results, presented above.

Implementation Guide

In summary the author's recommend that military physical conditioning programs include:

- two to four evenly spaced load carriage sessions per month;
- carried loads that are initially light yet progress in weight to meet that required for given military tasks;
- load carriage task durations and distances that gradually increase (yet not at the same time as increase in load) to meet military requirements;
- periods of recovery spaced throughout the program to allow the body to recover from the conditioning stimulus; and
- supplemental conditioning (muscle strength and aerobic training) sessions utilising functional movement patterns to provide adaptation to a broad spectrum of load carriage duties and tasks.

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Limitations of this review

Several limitations to the establishment of evidence of best practice and the subsequent guidelines issued in this paper are acknowledged. The heterogeneity of the populations in the identified research is high. While differences in motivation and experience can be found when comparing military and civilian participants, so too can differences be found across defence groups (comparing recruits in training and fully qualified soldiers, for example). Due to the limited number of core research papers focused on load carriage conditioning, the data could not be limited to only one such group and so all researched groups that undertook load carriage utilising systems akin to those in the military were included. Another limitation lies in the possibility that not all relevant papers may have been identified during the literature search. Likewise, military research papers that were rated above 'unclassified' could not be used in this public-domain review, due to security restrictions. Potentially limiting the application of the findings of this paper is its specificity. With the focus being on military load carriage, the generalisability of the results to other occupations which include load carriage will be limited primarily to those required to carry heavy loads on their backs, including fire fighters wearing breathing apparatus, special operations police and trail porters. The conditioning guidelines may, however, also be of use for recreational activities like distance hiking and mountaineering, where heavy loads are carried on the back.

Recommendations for future work

While this paper is able to provide some basic guidelines for physical conditioning for load carriage, specific intervention studies manipulating load carriage training doses in conjunction with established military physical conditioning regimes would be valuable to further progress information in this field.

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